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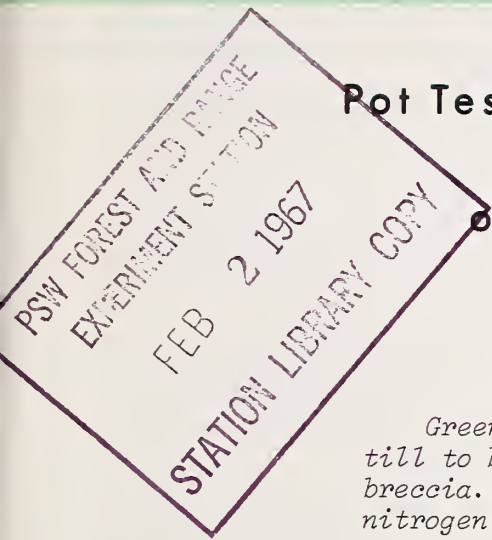
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION



## Pot Tests of Productivity and Nutritive Status of Three Alpine Soils in Wyoming

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*Greenhouse tests showed alpine soils developed on glacial till to be more fertile than those developed on volcanic ash or breccia. Phosphorus was limiting growth on till soils, and nitrogen was the limiting nutrient in ash and breccia soils.*

Management of high-altitude sheep ranges in Wyoming might be improved if we had more knowledge of the relative production and nutritive status of the soils. At the present time very little is known about the alpine and sub-alpine soils of these ranges. In the present study the surface soils from three distinct parent materials were subjected to laboratory analysis and greenhouse tests of productivity. Only the surface 6-8 inches of soil were studied. The results are presented here to help fill the gap in present knowledge.

### The Soils

Soil from glacial till was obtained from the Libby Flats area of the Snowy Range west of Laramie, Wyoming, at an elevation of approximately 10,500 feet. The soil was derived from glacial till containing a large amount of

quartzite. It was a very strongly acid, sandy clay loam with relatively high organic content (table 1). Such soils support a good cover of native vegetation typical of the Carex-Deschampsia community described by Johnson.<sup>2</sup>

Soil from volcanic ash was obtained from Carter Mountain, in the Absaroka Range west of Meeteetse, Wyoming, at an elevation of approximately 11,000 feet. These ash outcrops are very common throughout the Absaroka Range. Occasional native plants may be found, but in general the soils are devoid of vegetation.

The soil was a loam with some interesting characteristics. For instance, it was almost impossible to extract leachates in the laboratory. In the field, these soils become very boggy when wet from spring snowmelt, but later become very hard when dry.

Soil from volcanic breccia was obtained from the same general area as soil from vol-

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<sup>2</sup> Johnson, W. M. Vegetation of high altitude ranges in Wyoming as related to use by game and domestic sheep. Univ. of Wyo., Agr. Exp. Sta. Bull. 387, 31 pp. 1962.

Table 1. --Properties of three high-altitude soils from Wyoming

Item	Unit of measure	Glacial till	Volcanic ash	Volcanic breccia
Mechanical properties				
Sand	percent	58	41	59
Silt	percent	16	36	15
Clay	percent	26	23	26
Texture		Sandy clay loam	Loam	Sandy clay loam
Saturation	percent	56	56	39
Electrical conductance	mmho/cm.	0.8	0.2	0.2
pH (paste)		4.8	6.8	6.6
Organic matter	percent	6.5	0.0	2.9
Chemical analysis (extractable cations)				
Calcium	meq./100 g.	1.8	12.7	9.0
Potassium	meq./100 g.	.6	.9	.4
Sodium	meq./100 g.	.1	.4	.1
Magnesium	meq./100 g.	.3	11.6	7.6
Available phosphorus	p.p.m.	37.7	28.8	24.9
Nitrates <sup>1</sup>	p.p.m. of N	.7	.04	.04

<sup>1</sup> Values questionable because of delay between collection and analysis.

canic ash. The soil texture was very similar to that of the glacial till soil. The saturation percentage was lower, it was less acid, and it had a lower organic content. This soil also supports a good cover of native vegetation typical of the Carex-Deschampsia community.

### Methods

Two tests of the productivity of these soils were made, both by the same general procedures. Each soil was thoroughly mixed and sifted through a 1/4-inch-mesh screen. Nine hundred grams of air-dry soil were placed in 6-inch plastic pots. Seeds of the test species were planted in shallow depressions and lightly covered. After germination, each pot was thinned to five vigorous seedlings.

Distilled water was added to keep the soil at or about field capacity. Temperature in the greenhouse was maintained at  $70^{\circ} \pm 5^{\circ}$  F. Humidity and photoperiod were not controlled. The studies were made from October through May in 1962-63 and 1963-64.

Analysis of variance was used as a statistical tool, and a probability level of 0.05 was accepted as adequate protection for the interpretation of results.

The first greenhouse test compared the productivity of the three "natural soils." It was a randomized complete block design consisting of three replications. Two cultivated plants, oats (Avena sativa L.) and beans (Phaseolus vulgaris L.), and three native plants, Eggleston sedge (Carex egglestonii Mack.), ebony sedge (Carex ebenea Rydb.), and alpine avens (Geum rossii Ser.) were used as test species. It was hoped that one of the fast-growing cultivated species would respond in the same manner as native species so that it could be used in future tests to evaluate the response of native plants.

Numerous criteria were measured to evaluate the response of different species to the three soils. These criteria were: (1) percent germination, (2) average leaf height, (3) oven-dry weight of shoots, (4) oven-dry weight of



roots, (5) total oven-dry weight of plants, and (6) shoot-to-root ratios.

The nutrient status of the three soils was compared in the second greenhouse test, with oats as the test species. The experimental design was a randomized complete block with three replications. Treatments were a factorial arrangement of the following series:

Soils (3)

Glacial till

Volcanic breccia

Volcanic ash

Nitrogen (2)

N<sub>0</sub> (Check)

N<sub>1</sub> (80 pounds per acre)

Phosphorus (2)

P<sub>0</sub> (Check)

P<sub>1</sub> (200 pounds per acre)

Potassium (2)

K<sub>0</sub> (Check)

K<sub>1</sub> (200 pounds per acre)

Minor Elements (2)

M<sub>0</sub> (Check)

M<sub>1</sub> (Present)

Nitrogen was added as ammonium nitrate, phosphorus as calcium phosphate, and potassium as potassium chloride.

Minor elements were added at the following rates:

Element	Chemical	Pounds of element per acre
Boron	H <sub>3</sub> BO <sub>3</sub>	22.4
Manganese	MnCl <sub>2</sub> · 4H <sub>2</sub> O	24.7
Zinc	ZnSO <sub>4</sub> · 7H <sub>2</sub> O	2.5
Copper	CuSO <sub>4</sub> · 5H <sub>2</sub> O	2.8
Molybdenum	H <sub>2</sub> MO <sub>4</sub> · 4H <sub>2</sub> O	1.8
Magnesium	MgSO <sub>4</sub>	2.2
Iron	FeSO <sub>4</sub> · 7H <sub>2</sub> O	0.4
Calcium	CaSO <sub>4</sub> · 2H <sub>2</sub> O	5.0
Sulfur	(from above)	11.4

The elements required for each pot were dissolved in 100 ml. of distilled water. This solution was then added to the soil and thoroughly mixed.

Shoot and root production were used as measurement criteria.

## Results

### Productivity Tests

Germination of the various species was not significantly affected by kind of soil (table 2), but there was some indication that germination of oats and alpine avens was lower in the ash soil.

Production varied among the three soils; the nature of this variation depended upon the species. Glacial till, however, produced more oats, Eggleston sedge, and ebony sedge than did breccia and ash, which were equally productive (fig. 1). Means for alpine avens, though not significantly different, followed this same pattern. In every case, beans responded differently from the other species. Oats followed the same pattern of response as the native species, although the magnitude of the response was different.

The shoot/root ratio followed no consistent pattern. Each species reacted differently to the various soils.

Leaf lengths (fig. 1), root weight, and total weight of plants showed the same responses on the three soils as shoot production. In every case beans failed to respond in the same manner as other species. Oats followed the same pattern of response as the native species, although the magnitude of the response was different.

### Nutrient Status Tests

In the second greenhouse test, addition of the minor element solution depressed shoot production of oats on all soils. The effect was observed even before harvesting when the tips of the leaves turned brown and died. Evidently, one or more elements (perhaps boron) was added in toxic quantities. The magnitude of reduction in yield varied among the three soils. Micronutrients reduced production, when averaged over all other treatments, by 0.31 grams per pot on glacial till soils, 0.20

Table 2. --Summary of plant response to three mountain soils

Response by soil type	Unit of measure	Oats	Beans	Eggleston sedge	Ebony sedge	Alpine avens
Germination	Percent					
Glacial till		100	90	83	79	40
Volcanic ash		87	90	93	78	27
Volcanic breccia		100	90	97	76	53
Average leaf height	cm.					
Glacial till		30.0	22.5	17.6	18.2	6.3
Volcanic ash		15.7	26.1	4.6	3.4	2.3
Volcanic breccia		20.7	23.5	5.8	9.2	3.3
Ovendry weight, shoots	g. /pot					
Glacial till		1.31	2.06	1.77	1.84	0.31
Volcanic ash		.27	2.54	.14	.04	.05
Volcanic breccia		.45	2.02	.55	.12	.08
Ovendry weight, roots	g. /pot					
Glacial till		3.37	1.87	3.31	1.98	.23
Volcanic ash		.53	.88	.24	.12	.06
Volcanic breccia		.81	.86	.49	.19	.08
Total weight, plants	g. /pot					
Glacial till		4.68	3.93	5.08	3.82	.54
Volcanic ash		.80	3.42	.38	.16	.11
Volcanic breccia		1.26	2.88	1.04	.31	.16
Shoot -to-root ratio						
Glacial till		1: 2.55	1: 0.91	1: 1.87	1: 1.08	1: 0.74
Volcanic ash		1: 1.96	1: 0.35	1: 1.71	1: 3.00	1: 1.20
Volcanic breccia		1: 1.80	1: 0.43	1: 0.89	1: 1.58	1: 1.00
Duration of tests, all soils	Days	68	29	117	118	118
Stage of growth at harvest		Early bloom	Full bloom	Vege-tative	Vege-tative	Vege-tative

grams per pot on ash soils, and 0.10 grams per pot on breccia soils. In this case the soil  $\times$  micronutrient interaction was significant, and each soil responded differently.

The depressive effect of minor elements was increased by the addition of nitrogen. The toxic interaction of these two treatments was of the same magnitude on all soils. On the average soil, without nitrogen, yield was reduced by 0.9 gram per pot, but with nitrogen yields were reduced 0.33 gram per pot. Reasons for this response are not clear. In this case the soil  $\times$  micronutrient  $\times$  nitrogen inter-

action was not significant, and therefore all soils responded similarly.

The addition of potassium increased shoot production on the glacial till soils by 0.11 gram per pot, but decreased production on soils from volcanic ash by 0.07 gram per pot. Shoot production on soils from volcanic breccia showed a slight but not significant decrease.

The effects of phosphorus, nitrogen, and soils represent a complex interaction (fig. 2). Phosphorus alone increased shoot yield only



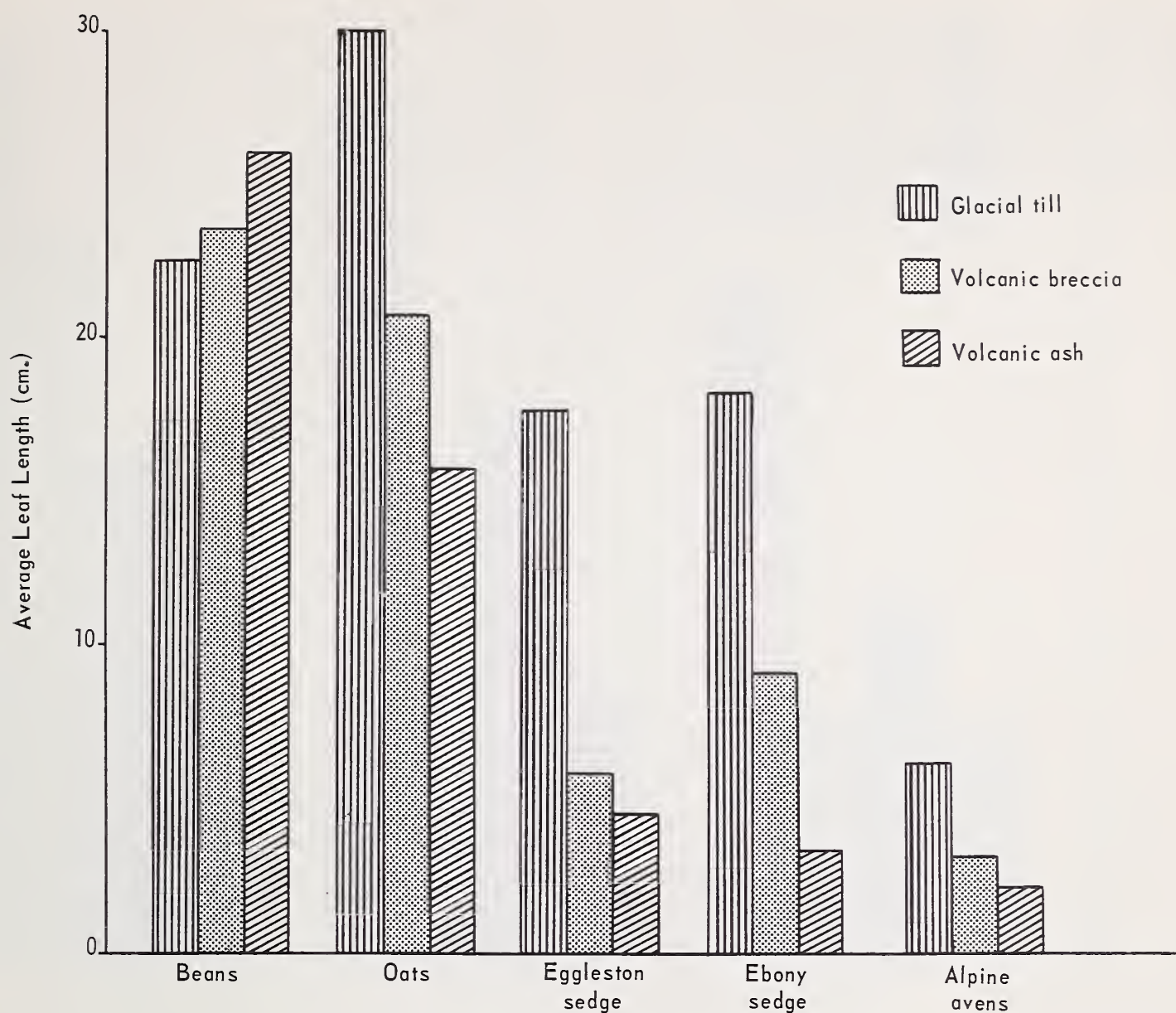


Figure 1.--Average leaf length of test species as related to soil origin.

on soil derived from glacial till. The increase amounted to 0.52 gram per pot.

Nitrogen alone increased shoot growth on all soils. The increase was similar on soils from ash and glacial till -- 0.21 and 0.16 gram per pot, respectively. The response on breccia was much greater -- 0.46 gram per pot.

The effect of nitrogen was complemented by phosphorus on ash and breccia, where phosphorus alone failed to increase yield. The complementary effect of phosphorus amounted to 0.51 and 0.50 gram per pot, respectively.

On soils developed from till, the effects of nitrogen and phosphorus were statistically independent.

Phosphorus increased the weight of roots on soil from glacial till by about 75 percent. The minor elements significantly retarded the development of roots in all soils. No other root responses were statistically significant.

#### Discussion and Summary

These greenhouse tests suggest that the soils derived from glacial till are naturally

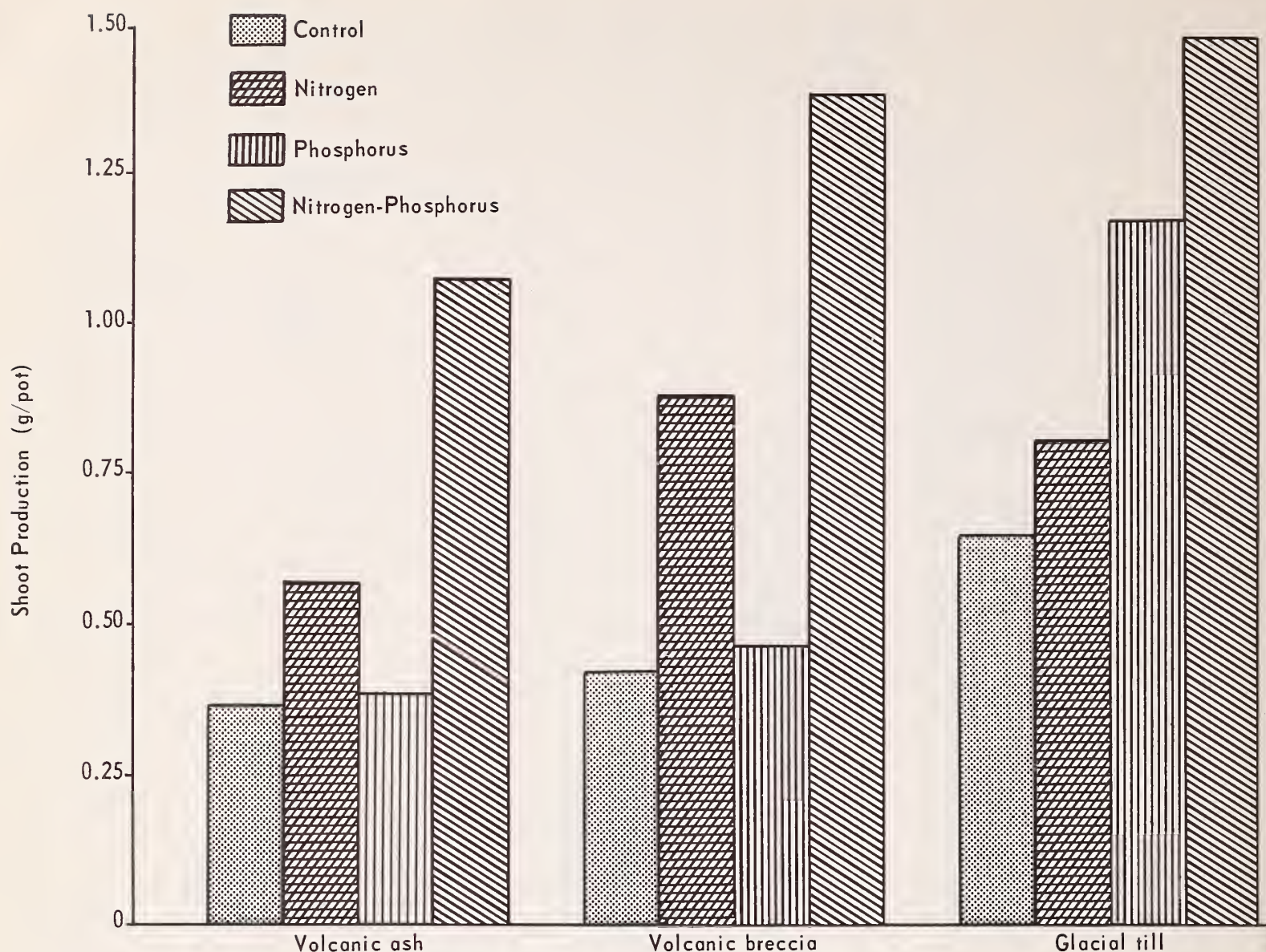


Figure 2.--Effect of nitrogen and phosphorus amendments on shoot production of oats on three soils.

more fertile than soils derived from either breccia or ash. They do support good stands of native vegetation. Phosphorus was the most limiting nutrient in this soil, although potassium and nitrogen fertilization also increased shoot production slightly.

Soils derived from volcanic breccia ranked next to the soils from glacial till in natural fertility. Nitrogen was the most limiting nutrient, but with nitrogen fertilization phosphorus became limiting. Maximum yields were obtained when both nitrogen and phosphorus were added to the soil.

Soils from volcanic ash were primarily deficient in nitrogen, and once nitrogen was supplied phosphorus became limiting. Although these soils did not grow any appreciable amount of vegetation in the field, they did produce vegetation, without fertilization, in the greenhouse where soil moisture was maintained at a favorable level. Other evidence, such as the extreme difficulty in obtaining extracts, the quicksandlike properties in the field when saturated, and the rocklike hardness that develops upon drying, also suggest that the natural sterility of these soils is related primarily to the moisture regime.



Greenhouse trials are not always indicative of field responses, but these studies do indicate that herbage production on soils from till and breccia may be increased through fertilization. Ultimate answers as to the practicality of such fertilization will depend upon field trials and economic evaluation.

Unless the soil moisture characteristics of ash soils are improved, there is little possibility of greater production through fertilization. Therefore, these soils should be accepted as being naturally unproductive and management plans made on this basis.

